UNIVERSITY OF UTAH

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

EL EN 3110

Electronics II

Midterm 2

November 19, 2001

NAME: KEY

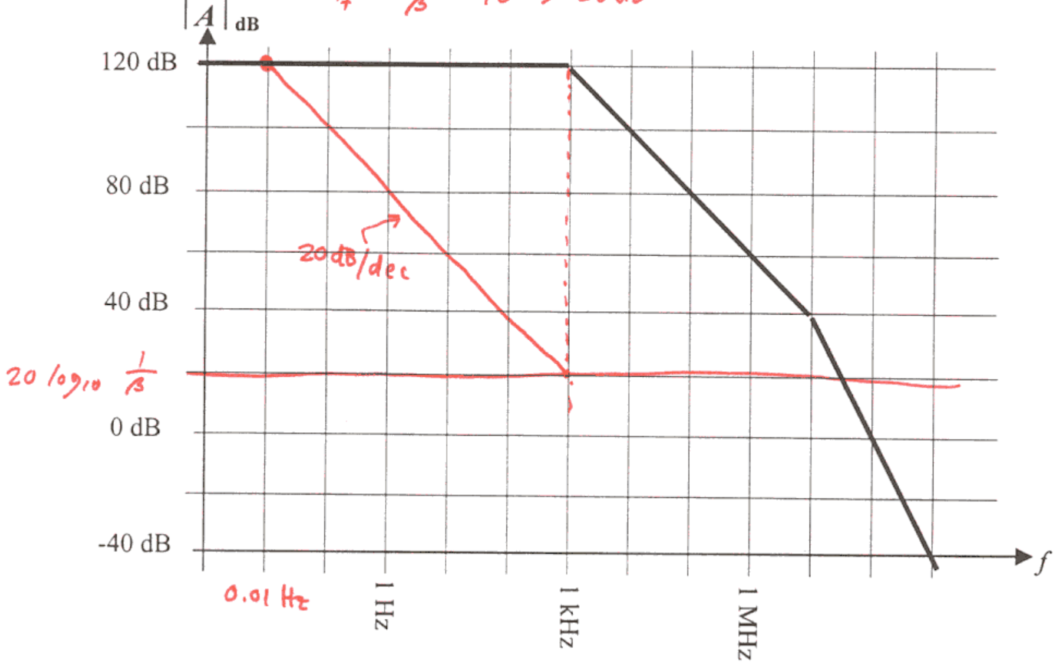
(Please print)

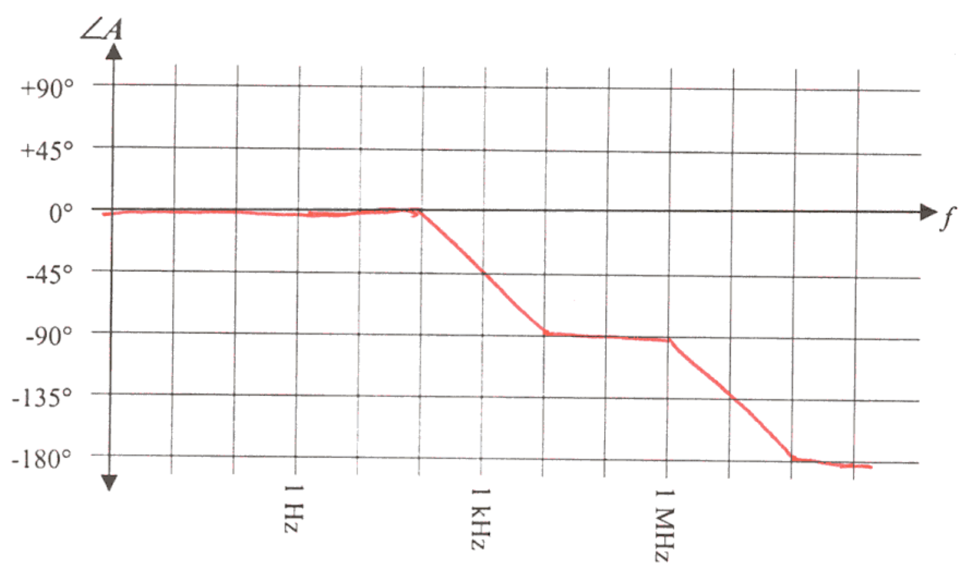
- Do not open the exam until instructed.
- Draw a circle or box around your final answers.
- All answers should include units (e.g., V, mA, kΩ) where appropriate. **For frequencies, use Hz (or kHz, or MHz), *not* radians/second.**
- If you want partial credit on incorrect answers, *show your work on the pages you turn in!* If you choose to turn in any sheets of scratch paper, *write your name on those sheets!*
- Don't spend all of your time on one difficult problem. Don't be afraid to skip ahead if you get stuck. You don't have to work the problems in order.
- Good luck!

1. (18 points) (a) Based on the magnitude Bode plot of an amplifier shown below, reconstruct the phase Bode plot in the space provided.

(b) At what frequency f_c should we add a pole to compensate this amplifier (for a phase margin of 45°) in a feedback network with a closed-loop dc gain of 10? f_c = 0.01 Hz

$A_f \approx \frac{1}{\beta} = 10 \Rightarrow 20\,dB$

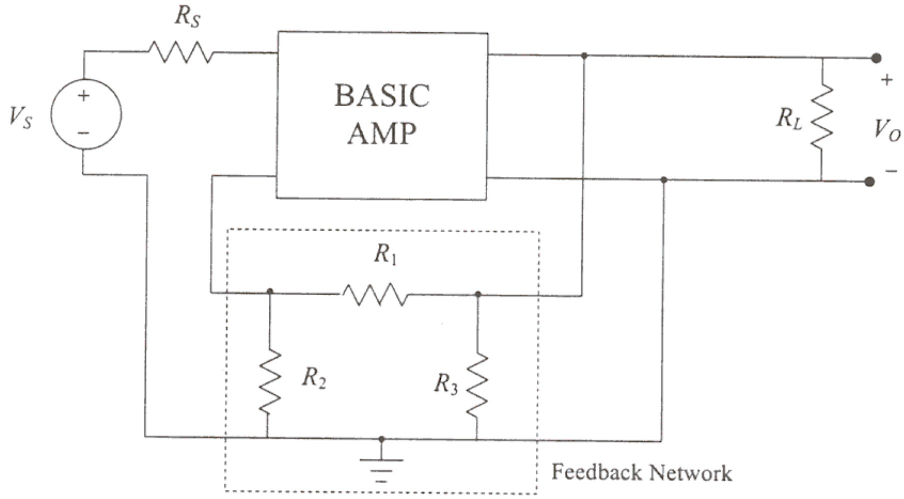


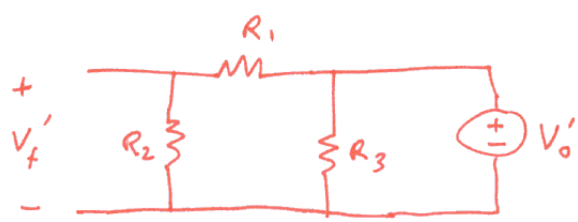


2. (18 points) What type of feedback topology is shown below (e.g., series-series, shunt-series,…)?

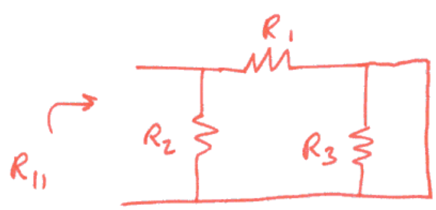
Series - shunt

Draw three pictures showing the circuit configurations used for measuring β, R_{11}, and R_{22} for the feedback network shown, and derive expressions for β, R_{11}, and R_{22} as a function of circuit parameters.

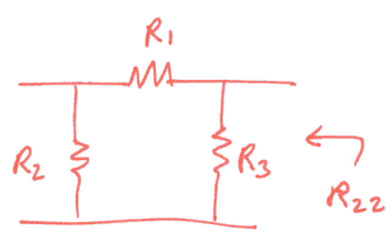




$$\beta = \frac{V_f'}{V_o'} = \frac{R_2}{R_1 + R_2}$$

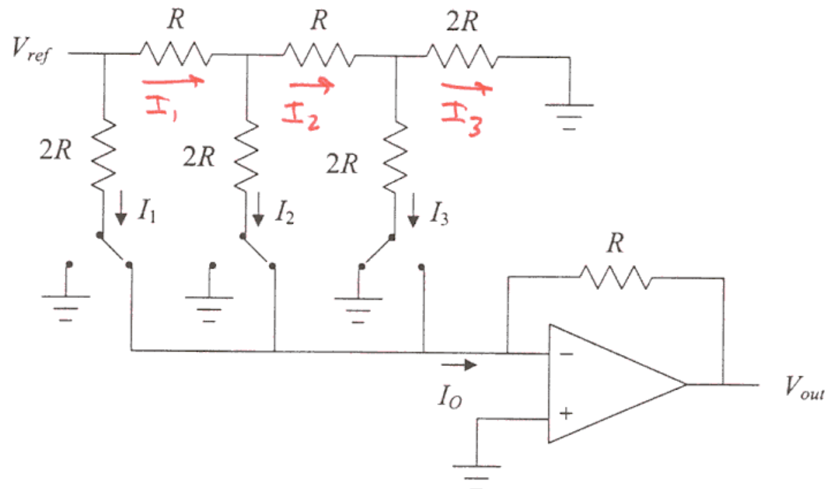


$$R_{11} = R_1 \| R_2$$



$$R_{22} = R_3 \| (R_1 + R_2)$$

3. (22 points) For the digital-to-analog converter shown below, $V_{ref} = 4$ V and $R = 500\ \Omega$.



- Find I_1, I_2, I_3, I_O, and V_{out}. (Note the position of the switches.)

$$I_1 = \frac{V_{ref}}{2R} = \frac{4\text{ V}}{1\text{ k}\Omega} = 4\text{ mA}$$

$$I_2 = \frac{I_1}{2} = 2\text{ mA}$$

$$I_3 = \frac{I_2}{2} = 1\text{ mA}$$

$$I_o = I_1 + I_2 = 6\text{ mA}$$

$$V_{out} = -I_o R = -6\text{ mA}(500\ \Omega) = -3\text{ V}$$

- To what binary input does this correspond? (This D/A converter produces an output of zero volts for the binary input 000.)

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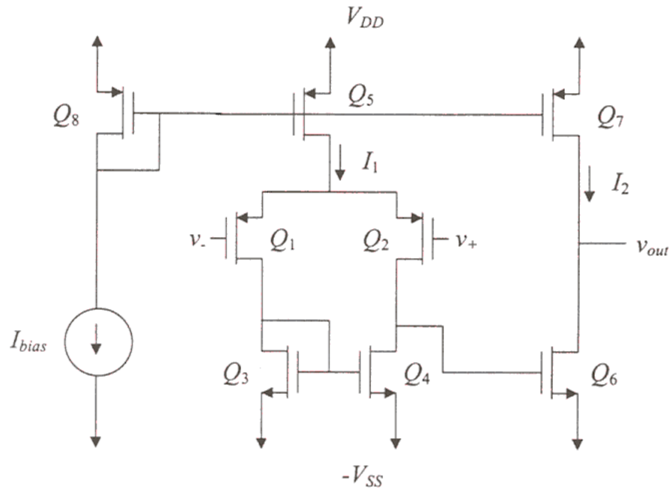
4. (20 points) A simple CMOS op-amp is shown below.



$V_{DD} = V_{SS} = 5$ V $\quad\quad I_{bias} = 20\ \mu$A

$\mu_p C_{ox} = 25\ \mu$A/V^2 $\quad\quad \mu_n C_{ox} = 75\ \mu$A/V^2

$|V_t| = 0.8$ V $\quad\quad |V_A| = 40$ V

$(W/L)_1 = (W/L)_2 = (W/L)_3 = (W/L)_4 = (W/L)_5 = (W/L)_6 = 100$

$(W/L)_7 = 400$ $\quad\quad (W/L)_8 = 50$

- Find I_1, I_2, g_{m6}, and r_{o4}. (Provide numerical values for each, *with units.*)

$$I_1 = \frac{(W/L)_5}{(W/L)_8} I_{bias} = \frac{100}{50} \cdot 20\mu A = 40\ \mu A$$

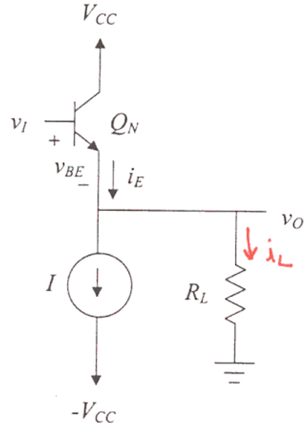
$$I_2 = \frac{(W/L)_7}{(W/L)_8} I_{bias} = \frac{400}{50} \cdot 20\mu A = 160\ \mu A$$

$$g_{m6} = \sqrt{2k_n'\left(\frac{W}{L}\right)_6 I_{D6}} = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right)_6 I_2} = \sqrt{2\cdot(75\mu A/V^2)\cdot 100 \cdot 160\mu A}$$

$$= 1.55\ mA/V$$

$$r_{o4} = \frac{V_A}{I_{D4}} = \frac{V_A}{I_1/2} = \frac{40\ V}{20\ \mu A} = 2\ M\Omega$$

5. (22 points) In the output stage below, V_{CC} = 15 V, I = 6 mA, and R_L = 1 kΩ. For transistor Q_N, $I_S = 10^{-13}$ A and β is very large.



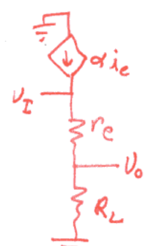
(a) Find i_E and v_{BE} (to at least 3 significant figures) in each of three cases: v_O = -5 V, 0 V, and +5 V.

$v_o = -5\,V \qquad i_L = \frac{v_o}{R_L} = -5\,mA \qquad i_E = I + i_L = 1\,mA$

$v_{BE} = V_T \ln \frac{i_E}{I_S} = 0.576\,V$

$v_o = 0\,V \qquad i_L = 0 \qquad i_E = 6\,mA \qquad v_{BE} = 0.620\,V$

$v_o = +5\,V \qquad i_L = 5\,mA \qquad i_E = 11\,mA \qquad v_{BE} = 0.636\,V$



(b) Use small-signal analysis to find the voltage gain v_o/v_i when v_O = +5V.

$$\frac{v_o}{v_i} = \frac{R_L}{r_e + R_L} = \frac{R_L}{\frac{V_T}{I_E} + R_L} = \frac{1\,k\Omega}{\frac{25\,mV}{11\,mA} + 1\,k\Omega} = 0.9977$$

(c) What is v_{Omin}?

$$\underbrace{\underbrace{\frac{v_{Omin}}{R_L}}_{i_L} + I}_{i_E} = 0 \quad \Rightarrow \quad v_{Omin} = -6\,V$$